

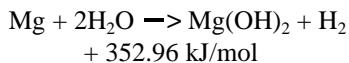
ALKALINE FUEL CELL TECHNOLOGY FOR MITIGATING HYDROGEN GENERATED BY Mg/Fe BASED CHEMICAL HEATERS

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ABSTRACT

The Unitized Group Ration - Express (UGR-E) is a disposable, compact, self-contained module that provides a complete, hot meal for 18 warfighters. The UGR-E contains four shelf-stable polymeric food trays that are coupled to four magnesium based chemical heaters (Figure 1). With the pull of a tab, the food is heated within 45 minutes. Unfortunately, upon activation, the magnesium based heaters release a hydrogen gas by-product according to:



Given that 400g of heater material is needed for the UGR-E, the amount of released hydrogen gas ($\sim 11 \text{ ft}^3$) is formidable and could pose a safety risk if the lower explosive limit is exceeded. In addition to mitigating this safety risk, it is also desired to use this energy (320 BTU/ $\text{ft}^3 \text{ H}_2$) in the form of either heat or electricity. To address this problem, a lightweight, affordable, disposable alkaline fuel cell (AFC) has been developed in a Phase I Army SBIR Contract. This novel approach is

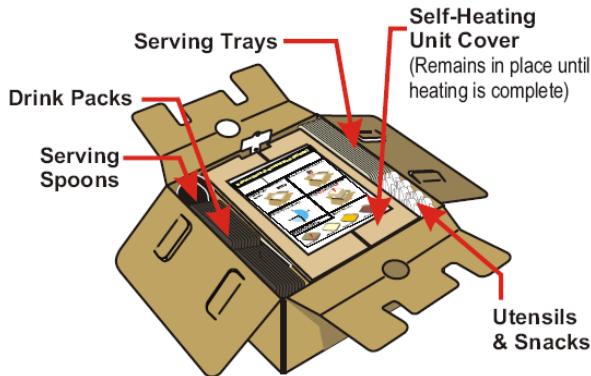


Figure 1. Unitized Group Ration - Express (UGR-E)

based upon using a micro-tubular AFC as a flexible heater cord (Figure 2). Although AFC technology has several perceived "drawbacks", our unique application found these to be an advantage:

- Longevity is not required, thus expensive electrodes (Pt, Au) have been replaced with Ni and NiCr wire.
- The electrolyte can be stored dry and then wetted upon heater activation. This eliminates electrolyte leakage and extends the shelf life indefinitely.
- Only operating for 45 minutes, CO_2 is unable to adsorb into the KOH electrolyte and precipitate K_2CO_3 .

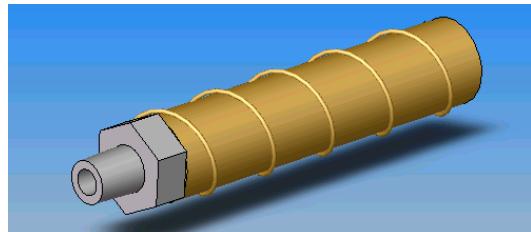


Figure 2. Pictorial representation of the AFC

During operation, hydrogen gas enters the interior of the tube, in which a long, thin ($\sim 10 \text{ mil}$) Ni wire is coiled to a diameter of 0.1 inches and serves as the anode catalyst. Ambient air reacts with a NiCr wire wrapped around the external surface, which acts as an oxygen cathode catalyst and current collector. Separating the electrodes is a 1-mil-thick polypropylene separator, which has been imbibed with KOH electrolyte to complete the fuel cell circuit. Generated electricity can then be passed through a resistive heater such as the NiCr wire electrode. In this manner, heat is generated along the length of the tubular fuel cell.

During this SBIR contract, electrode performance was improved through the addition of Raney Ni to the Ni wire anode and MnO_2 to the NiCr wire cathode. By optimizing the porous gas-diffusion electrodes with hydrophilic and hydrophobic compounds, decreasing the ohmic losses via improved electrolyte distribution, and increasing the kinetic activity by operating the cell at higher temperatures of 80 - 100 C, we can increase the operational current density of the AFC to 1-2 A/cm² as shown in Figure 3.

| Report Documentation Page | | | <i>Form Approved OMB No. 0704-0188</i> | |
|---|------------------------------------|-------------------------------------|--|---------------------------------|
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| 1. REPORT DATE 00 DEC 2004 | 2. REPORT TYPE N/A | 3. DATES COVERED - | | |
| 4. TITLE AND SUBTITLE Alkaline Fuel Cell Technology For Mitigating Hydrogen Generated By Mg/Fe Based Chemical Heaters | | | 5a. CONTRACT NUMBER | |
| | | | 5b. GRANT NUMBER | |
| | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) | | | 5d. PROJECT NUMBER | |
| | | | 5e. TASK NUMBER | |
| | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) MicroCell Technologies, Littleton, MA; U.S. Army Natick Soldier Center, Natick, MA | | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited | | | | |
| 13. SUPPLEMENTARY NOTES See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida. , The original document contains color images. | | | | |
| 14. ABSTRACT | | | | |
| 15. SUBJECT TERMS | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT UU | 18. NUMBER OF PAGES 2 |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | | |

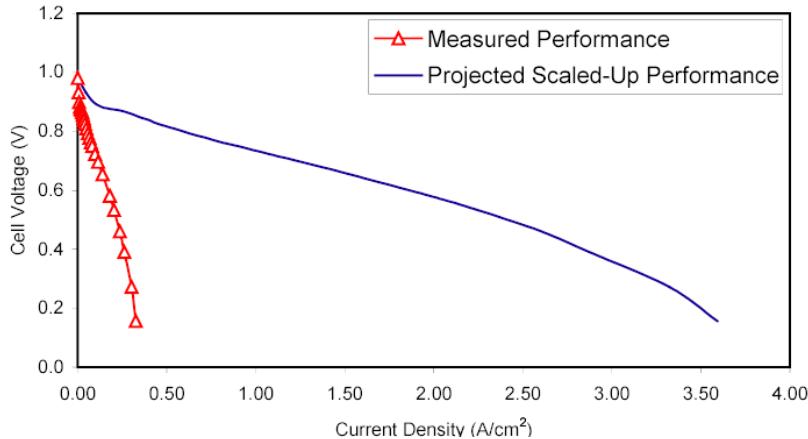


Figure 3. Expected performance improvement via improved electrodes and higher temperature operation

Based on projected operational current density of 2 A/cm², the required active surface area is on the order of 1000 cm² (Figure 4). This size AFC would weigh only 100 – 200g, a small fraction of the 30lb UGR-E unit. Based on these weights, the AFC will provide almost 20W/g of weight added, in the form of heat or power. In

the form of heat, this equates to almost 20% of the UGR-E heat output, leading to a reduction in the mass of magnesium heater required. More importantly, the hazard created by the hydrogen has been treated, while still yielding over 300 W-hours of power from the UGR-E; power that will ultimately benefit the Soldier.

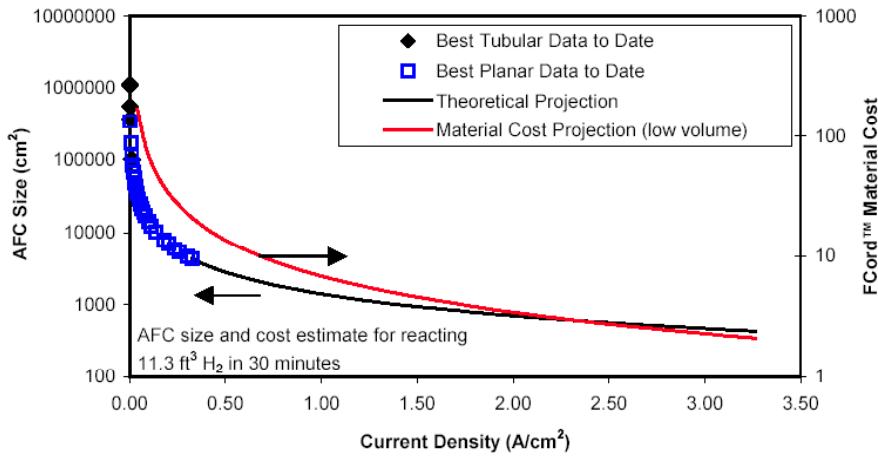


Figure 4. Size reduction of the AFC reactor/heater with increasing current density